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EXPERIMENTS IN THE USE OF SHEEP IN THE ERADICATION OF THE ROCKY MOUNTAIN SPOTTED FEVER TICK.

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PLAN OF EXPERIMENTS.

In order to test the destructive power of sheep against the spotted fever tick and to ascertain what importance sheep might play in the practical eradication of the tick, some experiments were performed by the Bureau of Entomology in the Bitter Root Valley in Montana in June and July, 1913. This work followed the announcement to the Montana State Board of Entomology, by Dr. L. D. Fricks of the Public Health Service, of observations on the death of ticks on sheep which have been published in the Public Health Reports of August 8, 1913.

Two experiments were performed, one with 20 sheep and the other with 2 sheep. The first experiment, with 20 sheep, which included 1 ram, 11 other adult sheep, and 8 lambs, was performed in country known to be well infested with ticks. The country over which the sheep ranged is adjacent to the foothills and is well supplied with bushes of various sorts, a growth of small pines, a few fairly large trees, and several streams of water. There was an abundance of grass along the streams, but under the pines next to the foothills there was little grass. In the ravine between two hills there was a thick growth of brush. It is next to the foothills, where brush abounds, that the ticks were found most abundantly. Very few ticks were observed along the streams and where the grass was growing in abundance.

Previous to the time the sheep were driven onto a school section which was used as an experimental pasture, they had been ranging away from the foothills and were probably quite free of ticks. No ticks were seen on cattle and horses running in the range from which the sheep were taken during the whole tick season, and the animals were under close observation by the owner. It is fair, then, to suppose that there could have been few, if any, ticks on the sheep at the time they were driven into " ticky " country.

In the evening of June 3 the sheep were driven onto the school section into a small corral previously prepared for them. On the morning of June 4, and thereafter until the evening of June 14, the sheep were herded twice a day for about two hours at each feeding. For the remainder of the time they were kept in the corral. About three-fourths of the time the sheep were herded, they were allowed to run at will, and the other one-fourth they were driven and made to feed in places known to be well infested with ticks. During all this time the development of the ticks was watched on some of the sheep, and when it was found that some of the ticks were nearly engorged the sheep were driven to the camp laboratory, about a mile from the sheep corral. At the camp the sheep were examined, usually twice a day, so that the development of the attached ticks might be followed, and any females that were engorged, or nearly so, were removed. Here the sheep were allowed their freedom the greater part of the day, but at night were confined in a shed. It is probable that they picked up a tick or two about camp, but probably only a very few.

Two thorough examinations were made of each sheep, to locate the living ticks and to remove the dead ones. The first examination began on June 10 and was finished on June 15; the second was started on June 23 and ended on June 27. Besides these examinations numerous less thorough examinations were made, any dead ticks found being removed and the living ones noted.

Near the completion of this experiment two sheep were selected from the adult sheep with heavy wool, and after thorough examinations were utilized in another experiment. Ticks were collected by dragging cloths over the ground and placed on these sheep. They were first put on one sheep June 20 and on the other June 25. Until June 28 these sheep were allowed to run with the others, but after that time the other sheep were driven back to the owner and the two were taken out to feed. They were examined twice a day.

OBSERVATIONS AND RESULTS.

In order to show as exactly as possible the results obtained, the 20 sheep have been divided into three groups, namely, unsheared lambs, unsheared sheep, and sheared sheep. In the first group were 8 spring lambs, Nos. 2–9, inclusive; in the second group were 7 adult sheep with heavy wool, Nos. 10–16, inclusive, and in the third group were the ram and 4 sheared adult sheep, Nos. 1 and 17–20, inclusive.

The results have been summarized in Table I. The heading, "total dead unfed ticks" includes all males and females which were thought to have been killed before having fed to any extent. It may also include, besides males which had not fed to any extent, males which had fed considerably, for it is usually impossible to distinguish fed

males from unfed males when they are dead. The headings under "location of dead ticks on host's body" are self-explanatory. The ticks taken from the head were usually in the wool on the top of the head. The same statement also applies to the neck. The heading, "total ticks found attached at first examination," is also self-explanatory. Only a few ticks were on the sheep at this examination. It is likely that there were only a few ticks which had attached themselves and become detached before this examination, except those which were found dead in the wool. The headings under "location of living attached ticks" need some explanation. The "other place" referred to in the case of No. 1 was near the base of the right fore leg, and in the case of No. 7 the tick was attached on the breast. Ticks attached on the head were in all cases found attached in the wool. No preference was shown by the ticks on sheep with heavy wool for places where the wool was short. They attached both in short wool and in long wool which was somewhat open. On the ram the ticks attached in a bunch in the cavity where the horn ordinarily is located (this ram was hornless).

All the ticks attached on sheared sheep, except one, were in front of the ears where the wool was thin; the exception was in the case of one tick which was attached on the shoulders.

TABLE I.—*Number of ticks, living and dead, found on sheep.*

No. of host	Sheared ram.	Unsheared lambs.							Unsheared sheep.							Sheared sheep.					Grand total.
	1	2	4	5	6	7	9	Total.	10	12	13	14	15	16	Total.	17	18	19	20	Total.	
Total dead unfed ticks:																					
Male	1	0	0	1	1	2	1	5	4	8	8	8	7	1	36	0	1	3	0	4	46
Female	1	3	0	3	0	2	1	9	8	13	6	10	15	2	54	1	4	0	0	5	69
Location of dead ticks on host's body:																					
Head—																					
Male	0	0	0	0	1	0	0	1	0	1	3	5	1	1	11	0	0	0	0	0	12
Female	0	1	0	1	0	0	0	2	3	4	0	5	1	2	15	0	2	0	0	2	19
Neck—																					
Male	1	0	0	0	0	0	0	0	1	0	3	1	3	0	8	0	1	2	0	3	12
Female	0	1	0	1	0	1	1	4	3	1	2	1	3	0	10	0	2	0	0	2	16
Back—																					
Male	0	0	0	1	0	2	0	3	1	5	2	1	2	0	11	0	0	0	0	0	14
Female	1	1	0	0	0	0	0	1	1	3	2	2	6	0	14	0	0	0	0	0	16
Sides of body—																					
Male	0	0	0	0	0	0	1	1	2	2	0	1	1	0	6	0	0	1	0	1	8
Female	0	0	0	1	0	0	0	1	0	4	2	2	5	0	13	1	0	0	0	1	15
Underparts of body—																					
Male	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Female	0	0	0	0	0	1	0	1	1	1	0	0	0	0	2	0	0	0	0	0	3
Total ticks found attached at first examination:																					
Male	4	2	2	3	0	1	7	15	4	3	0	0	0	0	7	0	1	0	0	1	27
Female	11	0	2	4	0	7	7	20	13	2	0	0	1	1	17	0	3	4	0	7	55
Location of living attached ticks:																					
Head—																					
Male	3	0	1	1	0	1	3	6	0	2	0	0	0	0	2	0	1	0	0	1	12
Female	10	0	0	0	0	6	5	11	3	1	0	0	1	1	6	0	3	3	0	6	33
Neck—																					
Male	0	2	1	2	0	0	4	9	4	1	0	0	0	0	5	0	0	0	0	0	14
Female	0	0	1	2	0	0	1	4	10	1	0	0	0	0	11	0	0	0	0	0	15
Shoulders—																					
Male	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Female	0	0	1	2	0	0	1	4	0	0	0	0	0	0	0	0	0	1	0	1	5
Other places—																					
Male	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Female	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Total ticks found crawling at first examination:																					
Male	0	0	0	0	0	0	1	1	1	1	0	1	0	0	3	0	0	0	0	0	4
Female	0	0	0	0	0	0	1	1	1	1	1	0	2	0	5	0	0	0	0	0	6
Total females known to have engorged one-half or more	3	0	2	4	0	7	4	17	1	0	0	0	0	1	2	0	3	4	0	7	29
Total females found with males beneath	3	0	1	2	0	5	4	12	2	0	0	0	0	0	2	0	1	0	0	1	18
Engorged females recovered from sheep	2	0	1	4	0	6	4	15	1	0	0	0	0	1	2	0	0	2	0	2	21
Engorged females dropped	(?)							(?)							(?)					(?)	1

On the lambs, ticks were found attached in several different places: Some were in front of the ears, some in the wool on top of the neck, others in the wool on the top and sides of the shoulders, and one was attached, as stated before, on the chest. In no case were the ticks on lambs found attached on the hind quarters or beneath the body.

The ticks referred to as crawling were no doubt those males and females which had recently gotten on the sheep, or perhaps they were males seeking females. Besides the females referred to in Table I as "engorged one-half or more," there were some other females which had fed slightly but had never become as much as one-half engorged. This division at one-half engorged is made because females less than about that size seldom lay eggs. Should ticks less than one-half full get rubbed off, it is extremely doubtful if they would ever deposit eggs. Just how many ticks were rubbed off or killed before complete engorgement it is impossible to say, but a few cases of this kind were observed. In all cases in which females are referred to "with males beneath," such pairs were in the correct position to effect fertilization. The "engorged females recovered from sheep," except one, were picked from the host when they had reached full or nearly full engorgement.

It seems probable that the dead unfed ticks found in the wool were for the most part killed by the lanolin, although the heat of the wool may have been a factor. It was found in a number of cases that ticks died after attaching. This factor was indicated by a reddish spot on the skin near the place where the tick was found dead. The ticks, however, were usually found loose in the wool. Both living (attached) and dead ticks were found at times in the same fold.

To show the location of the ticks recovered and the relation between shearing and the development of the ticks, certain data in Table I have been rearranged in Tables II and III.

TABLE II.—*Location of ticks recovered from sheep.*

	Dead.	Alive.
Head	31	45
Neck	28	29
Upper parts	30	[1] 5
Sides	23	0
Underneath	3	[2] 3

[1] On the shoulder. [2] Two on leg.

TABLE III.—*Relation between shearing and attachment of ticks.*

	Dead females.	Engorged females.
Lambs not sheared	9	15
Sheep not sheared	54	2
Sheep sheared (including ram)	6	4

The data appertaining to sheep numbered 3, 8, and 11 have been omitted from the tables because these individuals were dipped on June 13.

Special observations were made on sheep No. 10. On June 20, 9 females and 3 males, collected by dragging, were scattered on the back, neck, and head of this sheep. Most of the ticks went beneath the wool immediately near where they were dropped. On the forenoon of June 21 a male and a female were found dead in the wool, the female on the head and the male on the side. A female, nearly dead, was also found in the wool on top of the head. The live ticks attached were a male and a female on top of the head at a place where the wool was very short. Six males and 12 females, collected by dragging, were now scattered on the head, neck, and back. In addition 1 female (one-twelfth engorged) which was picked from a saddle horse was placed on the back of the sheep at the edge of a spot where the wool had been worn short. In the afternoon 3 males were found dead in the wool on the back. These had never attached. The one-twelfth engorged female was found dead and shriveled about 8 inches from where it was placed, in heavy wool. Eight males and 5 females, collected by dragging, were scattered on back, neck, and head. On the morning of June 22, 3 males and 1 female were found dead in the wool. Two males were taken on the shoulder and the other 2 ticks were taken from the head. None had attached. The live ticks found attached at this time were 4 females and 3 males, between the folds of heavy wool. Two of the dead ticks that were removed were taken from a fold where 2 females and 1 male had attached. The attached ticks were scattered as follows: 2 females and 1 male in a fold near each other; 1 male and 1 female near each other in another place; and 1 male and 1 female, each alone, at still other places. All were in long wool. A male, barely alive, was crawling at the edge of the short wool spot mentioned before. On the forenoon of June 23, 2 females and 1 male previously found attached were dead. These ticks were still attached when found. Two dead males and 3 dead females were also found. These had never attached. They were picked, 2 from the back, 2 from the head, and 1 from the neck. One of those on the back was a tick spoken of before as barely alive. At this time 1 female was found slightly engorged. A male was seen to be attached on the neck. A female loose in the wool appeared entangled. In the afternoon of this day 4 females and 1 male, collected by dragging, were put on the head, neck, and back of the sheep, as was also a male which had fed. All ticks went quickly under the surface of the wool. On the morning of June 24 the female that appeared entangled in the wool was dead. Three males and a female were picked from the wool, dead. These had never attached. Two females and 1 male were attached. The

2 females were ticks put on the day before. The male was attached before. Two females, 1 on the head and 1 on the back, were barely alive. On June 25, 2 dead females were picked from the wool on the head. They had never attached. One dead female was picked from the wool on the back. This tick was spoken of as barely alive. There were 3 females attached in long wool, 1 of which was engorged a little.

The following notes show the progress of the experiment:

June 27, a. m.: The 3 females are engorging to some extent. A male is under the largest of the three.

June 28: One of females on the head, which had begun to engorge, is now dead. This female was probably killed by the host. There are 3 females attached and feeding on the head. The largest is one-twentieth engorged.

June 29, a. m.: One dead male was taken from the neck and a dead female from the shoulder. The female had been attached. The one-twentieth engorged female is now missing.

June 30, a. m.: Two males and 2 females are attached on the head. Both females are feeding.

June 30, m.: One female, collected by dragging, was put on head.

July 1, a. m.: One female was picked from shoulder, which had never attached. The 2 males and 2 females are still attached as before. One female, collected by dragging, was put on the head. This female attached near one of the other females.

July 2: The female put on yesterday is attached as well as the other females. Two females are now one-twelfth engorged. The two males are attached as before.

July 3, a. m.: Three females and 2 males are now attached. The female put on sheep July 1 has moved one-half inch from its former place. Two females are about one-tenth engorged.

July 3, p. m.: One of the females that had become one-tenth full is now missing. The other is one-seventh engorged. Only 1 male was noticed attached.

July 5, a. m.: The female that was spoken of as one-seventh full is now full or nearly so and has a male beneath. This is the first time that a male has been seen near this female. The engorged female was picked.

July 6: One dead unfed female was picked from back. One male and 1 female are now attached.

July 7, a. m.: The male that was seen under the engorged female is now dead. It is crushed as though by the host. The female put on July 1 is now one-fifteenth engorged.

July 7, p. m.: A thorough examination was made at this time. Two dead females (unfed) and a dead male were picked from the back and sides of the sheep. The attached female is one-twelfth full.

July 8: The attached female is about one-sixth full. No males are near.

July 9: The attached female is about one-fifth full. No males are near.

July 10: The attached female is about one-fourth full. No males are near.

July 11: The attached female is about one-fourth full. No males are near.

July 12: The female is not attached, but is loose in the wool near its former place of attachment. It has begun to shrivel.

July 13: The female is dead in the wool at same place. It is shriveled and discolored.

The following notes record the observations on sheep No. 11:

June 23. The sheep thoroughly examined and no ticks found.

June 25, a m.: Four males and 11 females, collected by dragging, were put on the head, neck, and shoulders of the sheep. A male and a female of the foregoing were put in a fold close to the skin. The ticks put on the surface were out of sight in a few minutes.

June 25, p. m.: A dead male and a dead female were picked from the wool. The male had his head near the skin but had apparently never attached. Two females and one male were alive loose in the wool. The female that was placed in wool next to the skin is attached. The male is not where it was placed.

June 26, a. m.: A male and a female were picked from the head, both dead. These ticks had been attached. The female that attached in the fold where it was put is no longer there. No ticks are now attached.

June 27: Two females, collected by dragging, were put on the base of the sheep's ear; also 1 female (one-fourth engorged), picked from saddle horse, was put on the sheep's back. One dead unfed female was picked from the side. The tick had never attached.

June 28, p. m.: Two partly fed males were put on the head of the sheep. One of the 2 females put on the ear was found dead at the base of the ear. It had never attached. One female was loose on the head, crawling. The one-fourth engorged female was still alive, but has not attached.

June 29: Two males and an unfed female found dead in wool on the head. The partly fed female is now dead.

June 30, a. m.: One dead male was picked from wool on the head.

July 1: One female about one-twelfth engorged was picked from a saddle horse and placed in wool on the sheep's head next to the skin.

July 2: The partly engorged female is now dead.

July 9: No ticks were found after a thorough examination.

Table IV gives a summary of the experiments with sheep Nos. 10 and 11.

TABLE IV.—*Summary of experiments with individual sheep.*

Details.	Sheep No. 10.		Sheep No. 11.	
	Male ticks.	Female ticks.	Male ticks.	Female. ticks.
Total number ticks put on sheep	19	33	4	13
Total dead unfed ticks which never attached	15	13	5	4
Total ticks which attached but died quickly	1	5	0	2
Total ticks which fed some but died or were killed before attaining any size	1	2	0	0
Partly engorged females which died quickly when put on sheep	0	1	0	2
Total dead ticks recovered	17	21	5	8
Dead unfed ticks:				
From head	3	8	5	5
From neck	2	10	0	0
From back	8	9	0	0
From side	0	0	0	1
Total ticks known to have attached	4	7	0	1
Total female seen with males beneath	0	2	0	0
Total engorged females recovered	0	1	0	0

It is a fact generally recognized that animals in confinement will fight ticks more than animals running free. This fact will probably account for the small number of ticks which were successful in en-

gorging. The last female on sheep No. 10 would probably have become engorged had it been fertilized, for fertilized females engorge rapidly, whereas with infertile females engorgement is slow.

THE APPLICATION OF THE INFORMATION OBTAINED TO PRACTICAL ERADICATION.

The main point to be considered in the last experiment is the fact that of 33 females put on sheep No. 10, only 1 fed sufficiently to lay eggs. There were in all, however, 6 females which stood a fair chance of engorging, so that it is difficult to say what percentage of females that get on a sheep in nature will engorge to repletion. If we assume that 6 females would have fed to repletion in nature, we find that 5.5 per cent of those females which got on the sheep became engorged. In the experiment with 2 sheep, at the end of 6 days these animals had picked up at least 19 females, of which 13 females attached. At the same rate in 30 days sheep No. 10 would have had attached 80 females and would have picked up 94 females. If we take 5.5 per cent of 94 we have 5.17 females which would engorge to repletion in a month. We would have to assume this many to be the maximum for the sheep with heavy wool in the experiment. The minimum would be 0, since there were 2 sheep which had no females attached at the examination. It would be impossible to strike an average, but let us assume that each sheep would breed, on an average, 2 ticks per month. We would then have, for a herd of 1,000 sheep, 2,000 ticks per month during the tick season. Each female means about 4,000 larvæ. This would make 8,000,000 larvæ, which is a rather large number, though it is of course impossible to estimate what percentage of these would ever reach maturity. It might, however, be possible to eliminate the sheep which are likely to breed the majority of the ticks. Could this be done, it would be possible to use sheep in the destruction of ticks without dipping them. Until that fact is demonstrated, however, it would seem necessary to dip sheep along with other live stock in case they were allowed to run in "ticky" country. Even if it were not necessary to dip sheep with heavy wool, it would certainly be necessary to dip lambs or sheared sheep. A mere glance at the table will show that lambs or sheared sheep will breed a considerable number of ticks and kill but few. The only possibility, therefore, of employing sheep in the work of tick eradication would be the using of wethers of other sheep with heavy wool. It does not appear practicable to attempt to use wethers alone, under any circumstances, as a means of ridding the Bitter Root Valley of spotted fever ticks. Nevertheless it would appear to be possible to use sheep as one means of reducing the numbers of the ticks, although in this connection several considerations must be mentioned.

There would be some very serious objections to using sheep exclusively in the destruction of ticks, even though they should be found to kill practically all the ticks which get on them. In the first place, it would be necessary to eliminate all live stock except this on which the ticks could be destroyed at weekly intervals by dipping or otherwise. Secondly, it is impracticable to stock heavily a given area with sheep and attempt to carry the usual number of other live stock on the same pastures. It would thus be necessary to reduce greatly the number of live stock other than sheep in order to graze a sufficient number of sheep to have any appreciable value as collectors of ticks. Moreover, it would be necessary to cut down all vegetation higher than a sheep's back, for there are many ticks that await a host higher than 2 feet from the ground. It would also be necessary to drive the sheep where the ticks were known to be located, for the sheep naturally go where the feed is best. In the locality where the experiment with 20 sheep was carried on it was found that there were few ticks where the feed was abundant, but many next to the foothills and in the ravines where the feed was scarce. The character of the country on the western side of the valley in many places is also such that it would not admit of herding sheep. Should sheep run continuously in the wooded and brushy country on the western side of the valley they would wear off the wool, which would make them increasingly more susceptible to tick attack and less profitable to the owners.

The tendency of the tick to attach in bunches would indicate that in case ticks obtained a start on any animal they would breed on that animal with increasing facility; for it would be more easy, as the females enlarged, for the males to find them. Since most of the engorged females picked from the sheep in the experiment had males beneath them, and all of the females which were removed when well engorged deposited eggs which hatched normally, there appears to be little likelihood that there would be many females to drop which would not be fertile.

The possibility that sheep may serve as a reservoir for the virus of spotted fever is a point that should be tested before sheep are used at all in the destruction of ticks.

It appears, however, that sheep are very good collectors of ticks. Six sheep with heavy wool picked up in 11 days about 72 females and 47 males. Although no comparative experiment has been performed, it is the writer's opinion that 6 horses or 6 cattle under the same conditions would not have picked up and retained nearly that number. Therefore in "ticky" country which is favorable to the herding of sheep it would be advantageous to use sheep as collectors of ticks. By dipping the sheep once in 7 days it would seem that much good could be accomplished. To bring about the greatest good

it would be necessary to herd the sheep with a knowledge of the location of the ticks. It is extremely doubtful if sheep would be of much importance as collectors of ticks if they were allowed to run free.

The several limitations to the practicability of using sheep in the eradication of the spotted fever ticks that have been mentioned emphasize the great importance of following the plan of dipping domestic animals which is successfully under way. Sheep may be used under some conditions in the work, but the main reliance must be upon the dipping of horses and cattle. The extent to which sheep may be used will depend upon future experiments and observations.

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